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Relationship between age at menarche and body measurements among Mongolian girls

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Objective: Age at menarche is an important marker of female reproductive maturation and a predictor of future health outcomes. Although menarche timing is influenced by multiple genetic, environmental, and socioeconomic factors, the association between anthropometric characteristics and age at menarche among Mongolian girls remains poorly understood. Aim: This study aimed to investigate the relationship between anthropometric measures and age at menarche in Mongolian girls. **Methods:** Our study was conducted quantitative method, a cross-sectional study design among Mongolian school aged girls. To minimize recall bias, analyses were restricted to 317 girls who had attained menarche during the study year or within the preceding year. Anthropometric measurements, including body composition and body circumferences, were obtained using standardized procedures. Associations between anthropometric variables and age at menarche were evaluated using Pearson correlation and multivariable regression analyses. **Results:** The mean age of participants was 12.9 ± 1.4 years, and the mean age at menarche was 12.3 ± 1.3 years. Age at menarche was positively correlated with hip circumference, sitting height, and knee height (all $p < 0.001$), and negatively correlated with waist circumference ($p < 0.05$). No significant associations were observed for body fat percentage, body mass index (BMI), mid-upper-arm circumference, or birth weight. In multivariable regression analysis, waist circumference was independently associated with earlier menarche, whereas hip circumference and knee height were associated with later menarche. Strong positive correlations were observed among adiposity-related measures, particularly BMI, waist circumference, and hip circumference (all $p < 0.001$). **Conclusions:** Waist circumference, hip circumference, and knee height were significant anthropometric correlates of menarche timing among Mongolian girls, highlighting the potential role of body size and composition in pubertal development.

Keywords: Menarche age, Body mass index, Body fat percentage

Introduction

Menarche age is an essential marker of female pubertal progression and reproductive function. As an indicator of developmental timing, it has significant implications for long-term health, with evidence linking early and late menarche to various metabolic, cardiovascular, and endocrine outcomes.[1] Puberty represents a major physiological transition during which adolescent females develop secondary sexual characteristics and attain full reproductive capacity. This complex biological process is regulated by a delicate interplay of genetic and environmental factors, driven primarily by the reactivation and maturation of the hypothalamic-pituitary-ovarian (HPO) axis. Upon awakening during the peripubertal period, the HPO axis establishes a highly coordinated, pulsatile rhythm of growth and gonadotropin hormone secretion. The systemic elevation of these hormones accelerates somatic growth, triggers fat redistribution, and ultimately drives the physiological onset of first menstruation. Although the mean age at menarche typically ranges between 12 and 14 years across most populations, this timeline exhibits considerable inter-individual variation dictated by genetic predisposition, nutritional status, lifestyle, and socioeconomic conditions.[2]

A body weight of 44–47 kg and a body fat composition of 16–23.5% are considered the critical thresholds necessary for the onset of menarche in adolescent girls. The correlation between body mass and the age of menarche is primarily attributed to leptin, a key hormone involved in the regulation of body weight. Leptin is a peptide hormone synthesized and secreted by adipose tissue cells.[2]

Recent epidemiological and clinical evidence has consistently demonstrated that childhood anthropometric measures particularly body weight, stature, and body mass index (BMI) are closely associated with the age at menarche. Increased adiposity and higher BMI during the prepubertal period (5–9 years) are considered key physiological determinants that substantially raise the probability of early menarche (<11 years). Additionally, menarche age is associated with variations in regional adiposity. A negative association has been observed between menarche age and hip and thigh circumferences, whereby increased gluteofemoral fat mass corresponds to an earlier onset of menarche. Conversely, menarche age has been positively associated with waist circumference, stature, and biiliac breadth. This phenomenon is largely mediated by circulating leptin levels. Leptin, an adipokine secreted more robustly by gluteofemoral adipose tissue than by upper-body subcutaneous fat, acts as a critical peripheral signal. It conveys essential data regarding peripheral energy stores and fat distribution directly to the hypothalamus, thereby serving as a metabolic gatekeeper that initiates pubertal onset.[3]

The timing of menarche serves as an important indicator of long-term health outcomes. Early menarche (<12 years) has been consistently linked to an increased risk of adult-onset hypertension, glucose intolerance, and cardiovascular disease, as well as higher mortality associated with hormone-dependent malignancies.[4] Early menarche is recognized as an important risk factor for a range of adverse health outcomes.[5-7] Girls who experience early menarche are more likely to develop obesity in adulthood.[8] In contrast, delayed menarche (>14 years) is often linked to prolonged exposure to low estrogen levels during crucial stages of skeletal growth, potentially limiting the attainment of optimal peak bone mass. Consequently, reduced bone mineral density may increase the risk of osteoporosis and osteoporotic fractures later in life.[9] Consequently, examining the interrelationships among childhood body composition, regional adiposity, and menarche timing is an important step toward optimizing preventive healthcare approaches and designing effective adolescent health interventions. While a number of studies have assessed the growth and physical development of school-aged girls in Mongolia, relatively few studies have explored the association between physical development and age at menarche among Mongolian girls. The objective of this study is to examine the relationship between body mass index (BMI), body weight, height, and the age at menarche among the study participants.

Material and Methods

Study Subject

This cross-sectional study was conducted between May and July 2025 among Mongolian girls aged 8–18 years. A total of 2,700 girls were sampled from secondary schools offering education from grades 1 to 12, where students usually remain enrolled in the same institution until graduation. To reduce the likelihood of recall bias in reporting age at menarche, only girls who had experienced menarche during the study year or within one year prior to the survey were included in the analysis. Based on this criterion, data from 317 participants were analyzed. Data were collected through a structured questionnaire and physical measurements. The questionnaire included 25 questions on general demographic and socioeconomic characteristics and 35 questions related to menstruation and menarche. Furthermore, 14 types of anthropometric measurements were performed for each participant following standardized procedures. Anthropometric measurements were performed using standardized equipment. Body composition was assessed using a TANITA BH-730(Tanita Corporation, Tokyo, Japan). Height was measured with a stadiometer, circumferences were measured using a non-stretchable measuring tape, and handgrip strength was assessed using a handgrip dynamometer (T.K.K5001 GRIP-A , Tokyo, Japan). All measurements were conducted according to standard measurement procedures.

Statistical Analysis

The analysis was performed using SPSS, version 20.0 (SPSS inc.USA). Descriptive statistics was applied to observe data distribution. Pearson correlation analysis was used to assess the strength and direction of the relationship between age at menarche and anthropometric variables. Multivariable regression analysis was conducted to determine which anthropometric variables were independently associated with age at menarche after adjusting for the effects of other variables. Receiver Operating Characteristic (ROC) curve analysis was performed to evaluate the ability of individual anthropometric indicators to discriminate early menarche (<12 years).

Ethical statement

Ethical approval for this study was obtained from the Research Ethics Committee of the Mongolian National University of Medical Sciences (Resolution No. 24-25/08-02, April 25, 2025). The study protocol was reviewed and found to be in compliance with national and international ethical guidelines for research involving human participants, and permission was granted to conduct the study according to the approved methodology.

Results

The study included 317 participants with a mean age of 12.9 ± 1.4 years (range: 9.0–17.0 years). The average family size was 4.7 ± 1.2 members, and the mean birth order was 1.9 ± 0.9. Among female participants, the mean age at menarche was 12.3 ± 1.3 years, while the mean maternal age at menarche was 13.4 ± 3.4 years. Regarding place of residence, 119 (37.5%) participants lived in urban areas, whereas 198 (62.5%) resided in rural areas. The mean body fat percentage was 37.3 ± 8.54%, although the wide range observed (10.1–60.1%). The mean body mass index (BMI) was 20.1 ± 3.3 kg/m^2, ranging from 13.9 to 33.3 kg/m^2. The average mid-upper-arm circumference, waist circumference, and hip circumference were 23.7 ± 4.6 cm, 67.8 ± 7.6 cm, and 83.1 ± 8.9 cm, respectively.

Pearson correlation analysis demonstrated that age at menarche was positively correlated with hip circumference ($r = 0.280$, $p < 0.001$), sitting height ($r = 0.202$, $p < 0.001$), and knee height ($r = 0.226$, $p < 0.001$). In contrast, age at menarche showed weak negative correlations with waist circumference ($r = -0.131$, $p < 0.05$). No significant associations were observed between age at menarche and body fat percentage, BMI, mid-upper-arm circumference, or birth weight ($p > 0.05$).

BMI was strongly correlated with waist circumference ($r = 0.779$, $p < 0.001$) and hip circumference ($r = 0.674$, $p < 0.001$), and moderately correlated with mid-upper-arm circumference ($r = 0.442$, $p < 0.001$). Similarly, waist circumference showed a very strong positive correlation with hip circumference ($r = 0.822$, $p < 0.001$), indicating a close relationship between central and overall adiposity.

In multivariable regression analysis, waist circumference ($B = -0.044$, $p = 0.016$) was negatively associated with menarche age, indicating earlier menarche with higher waist circumference. Hip circumference ($B = 0.074$, $p < 0.001$) and knee height ($B = 0.053$, $p = 0.004$) were positively associated with menarche age. No significant associations were observed for BMI, body fat percentage, mid-upper-arm circumference, or sitting height.

ROC curve analysis demonstrated poor discriminatory performance of all anthropometric indicators for predicting early menarche (<12 years), with AUC values ranging from 0.341 to 0.473. Neither BMI nor body fat percentage showed acceptable predictive ability (AUC < 0.5), and all circumference and height-related measures similarly failed to discriminate early menarche cases.

These individual indicators alone were insufficient to predict or detect early menarche in girls; therefore, a combined predictive model was developed. The model demonstrated a predictive accuracy of 73% (AUC = 0.73, $p < 0.0001$).

Table1. Characteristics according to age menarche in participants

Variables	Mean	Standard Deviation	Minimum	Maximum
Age, years	12.9	1.4	9.0	17.0
Family members, n	4.7	1.2	1.0	9.0
Menarche age, years	12.3	1.3	8.0	17.0
Location				
Urban	119	37.5%		
Rural	198	62.5%		
Mothers' menarche age, years	13.4	3.4	0.0	19.0
Birth order, n	1.9	0.9	1.0	6.0
Body fat, %	37.3	8.54	10.1	60.1
BMI	20.1	3.3	13.9	33.3
Mid-upper-arm circumference, cm	23.7	4.6	15.0	78.0
Waist circumference, cm	67.8	7.6	50.0	96.0
Hip circumference, cm	83.1	8.9	60.0	113.0
Sitting height, cm	74.2	9.8	40.0	90.0
Knee height, cm	44.9	5.9	27.0	78.0
Systolic BP, mmHg	115.8	10.5	89.0	152.0
Diastolic BP, mmHg	75.1	9.6	44.0	106.0
Birth weight, gr	3366.4	399.3	2100.0	5300.0
Birth length, cm	50.8	3.4	28.0	60.0

Family members, BMI-Body Mass Index, body fat, sitting height, hip circumference, knee height, waist circumference, systolic BP, diastolic BP, birth weight, birth height, menarche, age years, urban, rural.

Table2. Correlation between age at menarche and anthropometric measurements

Variables	1	2	3	4	5	6	7	8	9
Menarche age, years	1	-0.058	-0.083	.140*	-.131*	.280**	.202**	.226**	-0.007
Body fat, %		1	0.024	-0.002	-0.009	-0.021	0.102	.192**	0.016
BMI			1	.442**	-779**	.674**	.202**	.160**	-121*
Mid-upper-arm circumference				1	.490**	.522**	.253**	.182**	.119*
Waist circumference					1	.822**	.215**	.201**	0.075
Hip circumference						1	.298**	.224**	0.100
Sitting height, cm							1	.520**	0.064
Knee height, cm								1	.162**
Birth weight, gr									1

BMI-Body Mass Index, body fat, menarche age, mid-upper-arm circumference, waist circumference, hip circumference, sitting height, knee height, birth weight

Table3. Associations between age at menarche and anthropometric measures of body mass index

Variables	B	Std. Error	Sig.	95% CI		VIF
				Lower	Upper	
Body fat, %	-0.019	0.014	0.181	-0.048	-0.009	2.199
Mid-upper-arm circumference	0.004	0.018	0.844	-0.032	0.039	1.466
Waist circumference	-0.044	0.018	0.016	-0.079	-0.008	3.849
Hip circumference	0.074	0.014	0.000	0.045	0.102	3.401
Sitting height, cm	0.006	0.009	0.452	-0.010	0.023	1.472
Knee height, cm	0.036	0.014	0.010	0.009	0.063	1.387

Body fat, mid-upper-arm circumference,waist circumference, hip circumference, sitting height, knee height

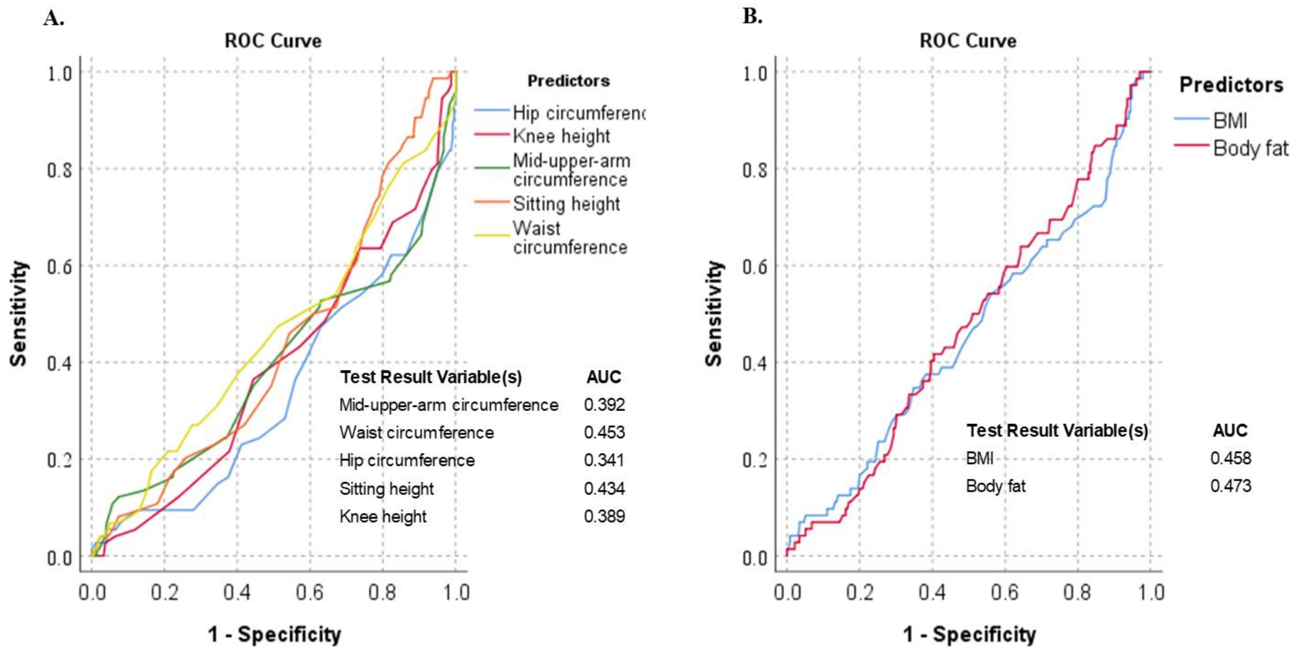

Figure 1.Prediction of early menarche based on body weight and metabolic disorder indicators.

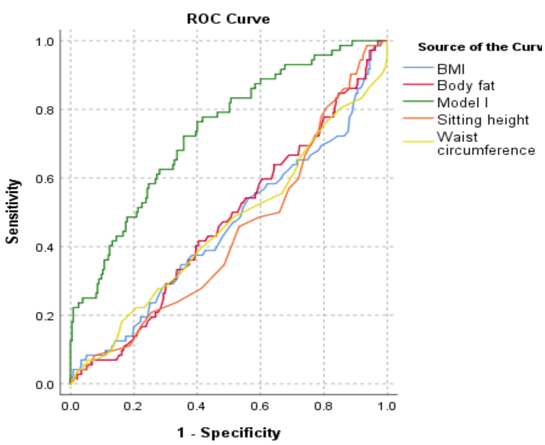

Figure 2.Combined predictive model for early menarche.

Discussion

Differences in anthropometric characteristics, such as body height and weight, between urban and rural girls may be associated with nutritional status and geographical factors. Girls living in urban settings often have greater access to diverse food sources and nutritionally adequate diets, which may promote more favorable growth patterns. As a result, urban girls tend to exhibit higher body weight and greater stature than their rural counterparts. These disparities in physical development may, in turn, influence pubertal maturation, particularly the timing of menarche. Previous studies have reported that girls who experience early menarche are more likely to be overweight or obese. Accordingly, excess body weight has been identified as a potential predictor of earlier age at menarche onset.[10] For example, a study conducted in the People's Republic of China found that girls residing in urban areas had greater body weight and height compared with those living in rural regions. In addition, the mean age at menarche was significantly lower among urban girls than among their rural counterparts (12.7 vs. 13.5 years, $p < 0.001$), indicating a possible link between nutritional status, physical development, and pubertal maturation. Despite the higher cost of living in urban settings, urban residents generally benefit from improved nutritional conditions and greater access to healthcare services, which may contribute to these observed differences.[11] Several hypotheses, supported by evidence from animal research, have been advanced to explain how increased body fat may promote the onset of puberty and menarche at an earlier age.[12,13] It has been proposed that the relatively high proportion of body fat (26–28%) observed in mature females may play a direct role in reproductive function. Several biological mechanisms have been suggested to explain this relationship. First, adipose tissue plays a role in estrogen synthesis through the aromatization of androgens, serving as a major extragonadal source of estrogen. Second, body weight and adiposity may influence estrogen metabolism by modulating the conversion of estrogens into metabolites with either greater or lesser biological activity; for instance, leaner women tend to metabolize a larger proportion of estrogen into catechol estrogens, which are characterized by reduced biological potency. Third, increased adiposity in women and adolescent girls may be associated with lower estrogen binding to sex hormone-binding globulin (SHBG), resulting in higher concentrations of bioavailable circulating estrogen. Finally, adipose tissue functions as a storage site for steroid hormones, thereby contributing to their retention and physiological regulation within the body.[14] While increased subcutaneous adiposity and elevated BMI have been identified as important determinants of earlier menarche in previous studies , our findings demonstrated only weak associations, with no statistically significant relationship between these measures and age at menarche.

Previous longitudinal and cross-sectional studies have consistently demonstrated an association between menarcheal timing and adiposity-related measures, including BMI and obesity, indicating that greater adiposity during childhood may contribute to an earlier onset of puberty and menarche.[15-18] Accordingly, early menarche has frequently been reported as a predictor of increased obesity risk later in life.[19] However, the causal direction of this relationship remains a matter of debate. It is unclear whether excess adiposity accelerates pubertal maturation, resulting in earlier menarche, or whether early menarche itself predisposes individuals to greater adiposity in later life. Furthermore, evidence suggests that the association between age at menarche and adult body composition may be largely attributable to prepubertal body composition, particularly during late childhood. In this context, age at menarche may reflect underlying childhood adiposity rather than exert an independent effect on subsequent body composition.[20] In contrast to these findings, our study did not observe significant associations between age at menarche and BMI or body fat percentage. This discrepancy may be attributable to differences in study design, population characteristics, sample size, or the timing of anthropometric assessment, as body composition was measured after menarche rather than during the prepubertal period.

The urban–rural differences observed in physical development may, in part, be attributable to variations in lifestyle and access to extracurricular activities. Urban children are more likely to have opportunities to engage in structured physical activities, including dance and sports programs, which may influence growth and body composition. For example, girls residing in urban areas may have greater access to extracurricular activities such as ballet and rhythmic gymnastics from an early age. Previous studies have reported that participation in these activities is associated with a later onset of menarche.[21] In contrast, opportunities to engage in such specialized training programs may be more limited in rural areas, which could contribute to differences in menarcheal timing and physical development between urban and rural populations. Furthermore, Kostrzewa, et al.[22] reported a substantially lower body fat percentage among ballet dancers aged 13–14 years compared with their non-athlete peers (14.5% vs. 28%). Body fat typically increases during adolescence as a consequence of growth, sexual maturation, and the endocrine functions of adipose tissue.[23,24] Insufficient adipose tissue accumulation, or a decline in body fat stores, may disrupt hormonal regulation and has been associated with menstrual irregularities and delayed onset of menarche. Consistent with findings from a Mongolian study of schoolchildren, significant urban–rural differences in physical development were observed, with the disparities becoming increasingly pronounced with age. Rural children demonstrated less favorable growth outcomes and a delayed growth pattern compared with urban children. The study also identified academic workload, place of residence, family size, living conditions, household income, and parental education as key factors influencing physical development, underscoring the complex interplay of socioeconomic and environmental determinants in child growth and maturation.[25] These factors may contribute to the later onset of menarche observed among girls residing in rural areas compared with those living in urban settings.

Age at menarche is a multifactorial trait influenced by nutritional, psychological, environmental, health-related, genetic, and socioeconomic factors.[26-29] Given Mongolia's distinctive geographic and climatic characteristics, environmental influences may contribute to growth, pubertal maturation, and variability in the timing of menarche among adolescent girls.

Our findings suggest that age at menarche is influenced by a complex interplay of multiple factors, and that anthropometric characteristics alone are insufficient to fully explain the variability in menarcheal timing among Mongolian girls. The timing of menarche is likely shaped by interactions among biological, environmental, and socioeconomic determinants. Therefore, future studies should adopt a comprehensive approach incorporating socioeconomic status, nutritional factors, psychological well-being, physical activity, body composition, and genetic influences to provide a more complete understanding of the factors underlying menarcheal timing in this population.

Conclusion

Overall, the findings indicate that waist circumference, hip circumference, and knee height are significant anthropometric correlates of menarche timing. Higher waist circumference was associated with earlier menarche, whereas greater hip circumference and knee height were associated with later menarche. Additionally, strong intercorrelations were observed among adiposity-related measures, particularly between BMI, waist circumference, and hip circumference. The strong association between waist and hip circumferences underscores the close relationship between central and overall adiposity in this population.

Conflicts of Interest

The authors state that there is no conflict of interest

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